EUV Interferometer

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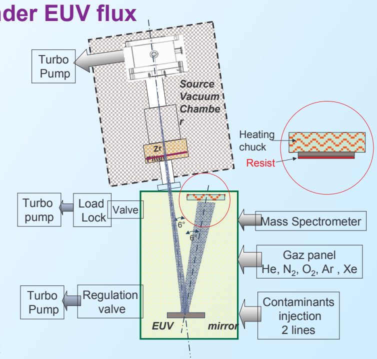
EUV lithography is the technology to address the 22 nm node, but resists development remains one of the key issue. First alpha tool EUV scanners have already been delivered to research centers, but suitable resists are still lacking. There is urgency to provide suitable tools to accelerate resists development with the necessary resolution. An interferometer lithography tool will provide the needed very high resolution compare to today alpha tool and mask limitation. Traditionally, a dedicated beam line from a synchrotron, with limited access, is used for light source in EUV interference lithography.
This poster describes the different technology issues to develop a stand-alone EUV interferometer using a compact EUV source.
Several optic designs were studied (double versus simple grating). For each of them, the source specifications and collimation optics have been determined.
EUV sources available on the market have been evaluated in terms of: power level, source size, spatial coherency, stability and reproducibility to meet the necessary specifications for interferometer lithography.
A new grating fabrication technology will also be presented allowing to significantly increase the transmission efficiency of the system.

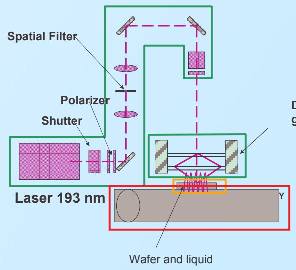
EUV Skills, know-how : Tools already developed by Leti

Outgassing tool development for studies resists outgassing under EUV flux



Functionalities :
1 – Commercial-resist out-gassing Characterization
2 – Potential Out-gassing Impact of resist Component
3 – Optics contamination Study

193 immersion interferometer



Functionalities
- Study of resist resolution limit in air and with liquid (n>1)

Critical issues:

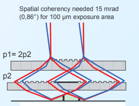
The following technical issues are identified :

- EUV source for interferometer application
  - EUV power
  - Source point stability
  - Source point size
  - spatial coherency
  - temporal coherency
  - particles emission
  - flux stability and reproducibility
  - solid emission angle
  - fluence
- Collection or collimation optics
  - design imposed by source characteristics
  - optical adjustment under vacuum
- gratings manufacture
  - manufacture of Silicone membrane
  - patterns providing on the membrane
  - manufacturing of double gratings (Ebeam write alignment in front of the grating below
- Gratings alignment
  - alignment between gratings under vacuum
  - alignment between last grating and wafer under vacuum
- Instrumentation and procedure of optical alignment
  - Alignment methodology to guaranty perfect optical alignment
  - moving mode identification
  - metrology identification
- Vibrations perturbation rejection

To give the best answer to each issues, multi technical know-how and skills are needed

Diffraction Gratings Design :

Double grating configuration



$\Lambda = \frac{\lambda}{2\sin\theta} = \frac{p_1}{2m} = p_2$

Print Pitch = pitch grating 2

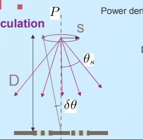
☹ cost constraint (sub mechanical system to support gratings)
☺☺ (Spatial coherency)☹ (level power) Source constraint
☹☹☹ high instrumentation mechanical capability constraint
☹☹ pitch limited by P2 (pitch second grating)

Advantages
Simple
2× on L&S density
DOF (limit?)
No alignments

Disadvantages
High spatial coherence required
Limited field
Contrast limited by temporal coherence
Photometry

Single grating calculation

Photometry



Power density at grating level

$E = \frac{P}{2\pi D^2 \theta_s}$

Distance source /grating

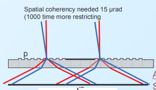
$D \geq \frac{s}{\delta\theta} = \frac{8.C_p}{\lambda}.s$

Exposure time

$t = \frac{Dose}{(E.Tg)}$

Cp (µm) print size	λ	s source size (mm)	Dmin = 8.Cp.s/λ (m)	P (W) sur 2pisr	θsource 1/2 angle (mrad)	E = P/(2π.D².θs) mW/cm² au wafer	Dose mJ/cm²	grating Transmission Tg %	tps = Dose*Tg/E s
100	13,5	1,00E+00	59,26	10	7	6,48E-03	10	12,5	12350
100	13,5	1,00E+00	59,26	130	7	8,42E-02	10	12,5	950
100	13,5	1,50E-01	8,89	130	3,5	7,49E+00	10	12,5	11
10	13,5	1,50E-01	0,89	130	3,5	7,49E+02	10	12,5	0,107

Single grating configuration



$\Lambda = \frac{\lambda}{2.\sin\theta} = \frac{p}{2}$

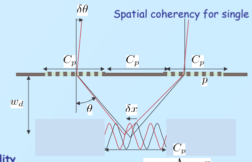
Print pitch = grating pitch / 2

☺☺☺ cost constraint
☺(power)☹☹(Spatial coherency) Source constraint
☺☺ mechanical constraint and less instrumentation
☹☹☹ print pitch = grating pitch divided by 2

Advantages
Simple
2× on L&S density
DOF (limit?)
No alignments

Disadvantages
High spatial coherence required
Limited field
Contrast limited by temporal coherence
Photometry

Spatial coherency for single level

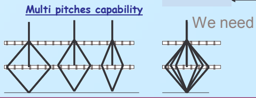


$\delta x = p.\frac{C_p}{\lambda}.\delta\theta$

$\delta x = w_d.\delta\theta$

$w_d = p.\frac{C_p}{\lambda}$

Multi pitches capability



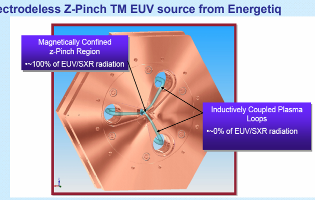
We need $\delta x \leq \frac{\Lambda}{4} = \frac{p}{8}$ so $\boxed{\delta\theta \leq \frac{\lambda}{8.C_p}}$

C_p	$\delta\theta$
100µm	17µrad
1µm	1.7mrad

EUV Source(s) :

The EUV source is a major part of the interferometer. The optical design is depending on the characteristics of the source.

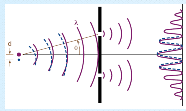
Electrodeless Z-Pinch TM EUV source from Energetiq



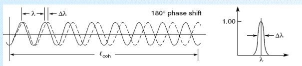
Energetiq source with inductively coupled Plasma Loops

Power : 2pi sr : 10 w in band (810^{-2} mJ/cm² at 60 cm)
Source point fwhm : 400 µm

Weight : 250 Kg
½ emission angle ≈ 1°
High stability
High reproducibility
Industrialized source

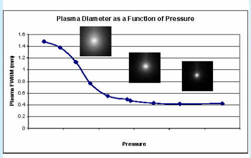


Spatial coherency



Temporal coherency

Controllable Plasma Size



In-band size is controllable via operating pressure.

Requirements :

Small size :
300 µm maximum size allowable
100 µm would be an optimum if possible in only one direction
:
=>Non symmetrical shape: Possibility of an astigmatic source?

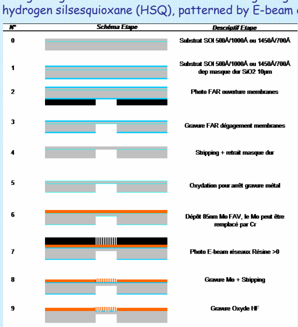
Power
available Density power (at the first Gratings) : 30 mJ/cm²

Emission angle
Maximum power in half aperture angle : 15 mrad (double)
15 µrad (single)

Contract development with Eppra is on working to evaluate the MMP/PCS EUV source

Gratings

The high absorption of Si3N4 material requires the use of extremely thin membranes (100 nm thick), which already absorbs 60% of the radiation at 13,5 nm wavelength.
In order to build a stand alone EUV interferometer with its own EUV source, which has less power than a synchrotron, we have to fabricate gratings with silicon membranes based on SOI substrate to improve the diffraction efficiency, reducing the absorption an attenuated light transmitted to less than 30%.
The grating is made on silicone membrane using inorganic resist, the hydrogen silsesquioxane (HSQ), patterned by E-beam exposure.



N°	Schéma Etape	Descriptif Etape
0		Substrat SOI 500Å/1000Å ou 1450Å/700Å
1		Substrat SOI 500Å/1000Å ou 1450Å/700Å dep masque dur SiO2 10µm
2		Photo FAR ouverture membranes
3		Gravure FAR dégagement membranes
4		Stripping + retrait masque dur
5		Oxydation pour arrêt gravure métal
6		Dépôt 85nm Mo FAV, le Mo peut être remplacé par Cr
7		Photo E-beam réseaux Résine >0
8		Gravure Mo + Stripping
9		Gravure Oxyde HF

Silicone Membrane process development

First Silicon Membrane
4 x 4 mm, 100 nm thickness

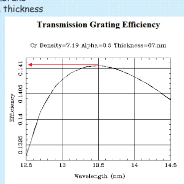
Membrane Si3N4
Patterns Cr (35/35nm)

⇒Transmission 7%
⇒ commercial Membrane
⇒ Etching Cr
⇒ Know how in Leti

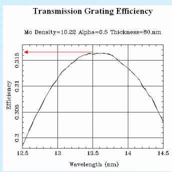
Silicon Membrane (100 nm)
Patterns Mo

⇒ Efficiency (30%) + transmission (80%) :Theoretical transmission 25 %
⇒ Membrane process development in hand
⇒ layer Mo and etching (process in Leti)

Double gratings
⇒ process to be developed

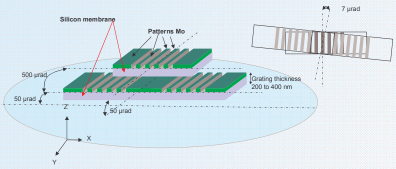


Cr grating efficiency (ratio space/ line 0.5, thickness 67nm maximum 14.1% for wavelength 13.5nm.

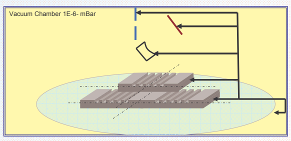


Mo grating efficiency (ratio space/ line 0.5, thickness 80nm maximum 31% for wavelength 13.5nm.

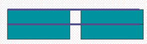
Mechanical setting up



Tolerances
- Parallelism between both gratings : 500 µrad
- Parallelism P2/ wafer : 50 µrad
- alignment rotation axe grating 1 / grating 2 : 7 µrad
- X alignment : several nm
- Y alignment : several µm
- Z alignment : around several 10 nm
- DOF 500 nm, minimal step precision : 10 nm
- Max vibration amplitude into the scale frequency [0,200 hz]
  1/8 CD it's mean 2 nm for a CD equal to 15 nm



-Very strong fixation between grating, wafer, pinhole and optic collimation during the exposure time
- All mechanical parts place in vacuum chamber (10-6mbar)
- Possibility to adjust position from the outside of the chamber
- Identification of the minimal measurements of the positions on EUV light before vacuum and after vacuum.



Double gratings made by direct manufacturing

Conclusion :

To develop the needed interferometer, we must address the following issues at an acceptable cost and delay :

- Source coherency
- Source brightness and fluence
- Grating efficiency
- Mechanical adjustments under vacuum capability
-

The stand alone interferometer will be interesting only if it is able to address the 22 nm node with various pitches in acceptable printing time for resist sensitivity around 10 mJ/cm².